Quantitative Assessment of Blood Flow with 4D Phase-Contrast MRI and Autocalibrating Parallel Imaging Compressed Sensing

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Purpose: Quantification of blood flow is an essential part of the congenital heart MRI exam, generally performed with 2D phase-contrast MRI (PC-MRI). 4D PC-MRI, because of its volumetric nature, may reduce operator-dependence, but is lengthy. Combined parallel imaging and compressed-sensing may reduce imaging time and improve image quality. However, it is unclear whether flow measurements remain accurate with a nonlinear compressed-sensing image reconstruction. Here we assess the accuracy of flow quantification using these techniques.

Materials and Methods: Patients referred for cardiac MRI evaluation were recruited for a 4D PC-MRI with intravenous gadofoveset. 13 patients were included (4 months-10 years) with a body surface area (BSA) of 0.3-1.37 m2. The 4D scan used poisson-disc k-space undersampling; images were reconstructed with both parallel imaging alone (ARC, GE) and with compressed-sensing (L1-SPIRiT) separately applied to each flow-encoding. Exams were performed with flip angle 12-15°, TR 3.74-5.35, TE 1.36-2.16, 2-4 views/segment, and ky and kz total acceleration factors of 1.6-5. Ventricular volumes and 2D PC-MRI flow calculations were performed on a GE Advantage workstation. Custom software was developed for 4D PC-MRI flow and ventricular measurements.

Results: 4D PC flow rates at the aortic and pulmonary valves were tightly-correlated with and without compressed-sensing (Qs: r=0.97, Qp: r=1.00), spanning flow rates from 0.85-5.79 L/min. Using L1-SPIR-iT, 4D PC flow rates also correlated well with 2D PC (Qs: r=0.94, Qp: r=0.98), even with combined acceleration as high as 10x. Despite the presence of valvular regurgitation, these flow rates also correlated with cine SSFP ventricular volumes (Qs: r=0.87, Qp: r=0.87) and 4D PC-MRI ventricular segmentations, (Qs, r=0.86), with no mean difference on Bland-Altman analysis.

Conclusions: We demonstrate nearly identical quantitative blood flow measurements can be obtained from 4D PC-MRI with parallel imaging alone (ARC) or with a nonlinear compressed-sensing reconstruction (L1-SPIR-iT). Measured flow rates also correlate well with 2D PC, SSFP and 4D PC-MRI volumes.